FAA Technical Center
Airborne systems Technology Branch, ACD-330
Atlantic City, NJ

Flight Test of Ashtech GPS Receiver For Use as Time Space Position Information System (TSPI) To Verify Specific Performance Standards

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1.0 Introduction.

The Federal Aviation Administration Technical Center Airborne Systems Technology Branch, ACD-330, is currently involved in precision and non-precision approach flight testing using the Global Positioning System (GPS). Advanced techniques in signal processing including carrier phase tracking have enabled new augmented GPS receivers to greatly increase their degree of accuracy. To evaluate precision approach systems, a reliable truth source with decimeter accuracy is required. To satisfy this need, the Technical Center through a cooperative effort with Transport Canada, has conducted tests to validate a portable truth system with precision accuracy, known as the Time Space Position Information System (TSPI). The FAA Technical laser tracker was used as a base line in these tests. It's one sigma accuracy is specified to be 0.1 milliradian in azimuth and elevation and one foot in range.

The TSPI system tested employs a technique commonly known as differential GPS, where the final solution is based on precise carrier phase measurements. This process requires one GPS receiver on the desired platform (aircraft) and a second receiver placed at a known surveyed point. The two receivers run simultaneously collecting GPS satellite data to calculate their position. The GPS receiver placed at the survey point compares its known position with its calculated position and determines the anomalies caused by ionspheric conductions and selective availability. The anomalies may then be transmitted as corrections in real time to be incorporated into the platform GPS receiver's final calculated position. For this evaluation, the TSPI was only tested using post processed corrections.

2.0 Objectives.

2.1 Accuracy.

The primary objective of these tests was to determine the accuracy of the TSPI system. In determining the results, Along-Track, Cross-Track, and Vertical differences between the laser tracker position and the TSPI position were observed.

2.2 Dynamic Performance.

The dynamic performance of the TSPI system was tested by its ability to continuously provide 1 Hz position update while the aircraft performs fundamental turns and descents. Specifically, the airborne receiver was observed to determine if it experienced a loss of lock on any satellites, to determine the time in which the receiver takes to require a position, and to determine inherent lags in the system response.

3.0 Tests.

3.1 Equipment/Software.

The TSPI system under evaluation was the Ashtech Z-12 GPS receiver. The basic components of the system are two Z-12 GPS receiver, each with its own microstrip antenna and power source. The system provides surveying, navigation, and tracking capabilities. Each Z-12 receiver may be used as either a ground reference station or as an airborne receiver during the flight test. Once flight data has been collected, Ashtech's post processing software was used to merge the data from the ground station and the airborne receiver to produce accurate positions.

3.2 Static Ground Tests.

To isolate any errors related to dynamics and the laser tracker data, the TSPI was set up at the Atlantic city Airport on a (First Order) National Geodetic Survey (NGS) surveyed point (1 to 2 mile baseline) and static data was collected. The data, was post processed and final position using satellite data was determined. The known Latitude, Longitude, and Ellipsoid Heights of the NGS surveyed points were then compared to the calculated points to determine if any biases occurred.

3.2 Flight Tests.

Flight tests took place aboard the FAA Technical Center's Aerocommander 680 (tail number N50). The test environment consisted of a racetrack approach path onto runway 13 at the Atlantic City Airport. Navigation data was collected for approximately 26 approaches starting at 4 nautical miles out on final approach and ending at the runway threshold. The approaches were collected on two separate days. (14 the first day and 12 on the second day)

To assist in our analysis, additional data was collected aboard Transport Canada's Challenger at Crows Landing, CA. Using the same racetrack approach path, 46 approaches were collected onto runway 12 over a four-day period. This data was then sent to the FAA Technical Center for analysis.

4.0 Conclusions.

4.1 General

The Ashtech Z-12 TSPI proved to be a robust system. The receivers tracked all satellites observed in the sky and had no trouble retaining lock on the satellites. On a number of occasions the airborne receiver was turned off and on to determine the time to regain satellite lock. On each occasion, it took less than 90 seconds to regain lock and compute an updated position.

4.2 Static Accuracy

Data collected at the known surveyed point utilizing the Ashtech Z-12 static mode demonstrated excellent accuracy. When the known NGS survey point was compared to the point calculated by the TSPI, the results were all within 2.2 centimenters in the Latitude, Longitude, and Ellipsoid Height measurements (See Figure 1). This demonstrates the Ashtech Z-12 GPS receiver's high degree of accuracy in the static mode.

	NGS Survey	**TSPI Survey**	**Difference**
Latitude	N 39 28' 08.60987"	N39 28' 08.60915"	2.2 cm
Longitude	W 74 34' 15.20895"	W 74 34' 1520846"	1.2 cm
Ellipsoid Height	-12.364 meters	-12.375 meters	1.1 cm

Figure 1. Static Results.

4.3 Statistical Spreadsheet Analysis

The following information is provided to assist in understanding the statistical analysis spreadsheets (Appendix B)[1] :

1. Each spreadsheet consists of two pages. Each spreadsheet is reflective of specific aircraft and location. (i.e. Aerocommander, Atlantic City Airport.).

2. The spreadsheet displays the point position error as a function of distance from runway threshold (in increments of 0.1 nm) VS the approach number.

3. The point position error is defined by the difference between the Laser Tracker and the TSPI position in meters.

4.4 Airborne Accuracy.

When comparing the statistical spreadsheets of Atlantic City and Crows Landing, the SD at each 0.1 NM demonstrates the consistency of the TSPI. For example, four sample vertical position differences between Laser Tracker and TSPI are illustrated in Figure 2.

Vertical Difference between Laser Tracker Position and TSPI Position		
Distances	Atlantic City Airport (SD)	Crows landing (SD)
4.0 NM	0.52 m	0.50m
3.0 NM	0.26 m	0.39 m
2.0 NM	0.27 m	0.34 m
1.0 NM	0.23 m	0.20 m

Figure 2. Samples of Standards Deviations.

[1] In the Atlantic City statistical spreadsheets, some position differences are missing from 0.6 nm to the threshold. This is a result of the pilots having to turn off the approach early due to runway construction.

The SD throughout the Along-Track and Cross-Track compare similarly, demonstrating the TSPI tracks consistently over the whole approach. It is also observed at the decision height of 200 feet, the vertical position difference are 42 cm and 34 cm at 2SD (95%).

For most statistical analyses, it is desired to calculate the 2SD + mean to conclude the true accuracy of a system. The mean calculated in the flights conducted at Atlantic City Airport is near zero (0.01 meters). The average mean at Crows Landing was calculated to be 1.25 meters for the lat 4 NM. It is thought that this large mean results from one or a combination of the following; erroneous survey data or reference station not aligned correctly.

Upon examination of the composite plots from the Crows Landing approaches, (See Appendix A), it is evident from the Cross-Track and Vertical Sensor Errors, that the closer the aircraft got to the threshold, the smaller the bias. The laser tracker is an angular range system, hence the ramping effect. It is believed the laser error is the predominate in this set of data.

There are two differences in the laser trackers used for this test that may account for the large mean in the Crows Landing data. The Crows Landing laser tracker is specified as only half as accurate as the Atlantic city laser (0.2 milliradian azimuth and elevation, one sigma) and it is located approximately 6000 feet from the touchdown point compared to 4000 feet at the Atlantic City Airport. From the data, it appears that the TSPI is more accurate then the laser tracker used as a truth source to test it.

Based on the one sigma distribution of the Z-12 tracking accuracy at both Atlantic City and Crows Landing when near the threshold, the 95% accuracy is estimated to be better than 40 centimeters.

4.4 Recommendations.

The results from these tests demonstrate precision accuracy in the Along-Track, the Cross-Track, and Vertical ranges. Based on the combination of user friendliness, portability, and 40 centimeter 2 SD accuracy, the Ashtech Z-12 GPS receiver meets requirements to be used as a truth source in Category I type flight tests. Additionally, the Z-12 appears to be adequate for Category II & III flight tests where a laser is not available.